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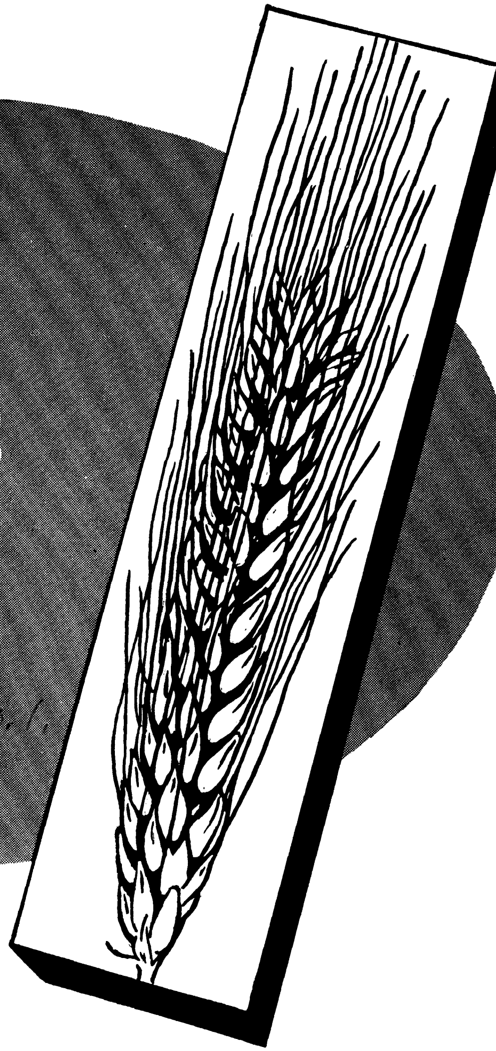
BARLEY DISEASES and Their Control



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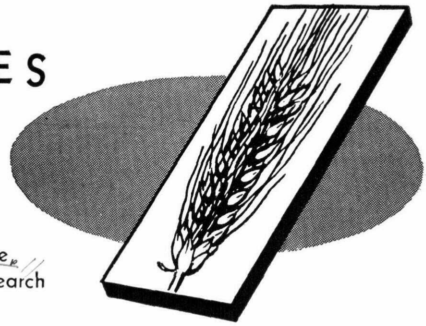
BARLEY DISEASES

and Their Control



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By R. W. Leukel, pathologist, and V. F. Tapke, formerly senior pathologist, Field Crops Research Branch, Agricultural Research Service

Barley ranks fourth in value among the cereals grown in the United States. In 1950 over 301 million bushels of barley, with a value of about $351 million, were produced on slightly over 13 million acres. Barley diseases reduce the annual yield by at least 5 percent, or about 15 million bushels.

Much of this loss can be prevented by using approved control measures, such as the planting of disease-resistant varieties, proper crop rotation, seed treatment, and proper tillage methods that dispose of disease-harboring materials in the field.

One must be able to recognize the diseases in order to successfully combat them. The principal barley diseases are described herein, and methods are suggested for their prevention or control.

SMUTS OF BARLEY

Covered smut, nigra loose smut, and nuda loose smut are important diseases of barley in the United States.

COVERED SMUT

Covered smut destroys ½ million to 4 million bushels of barley annually in the United States. This disease first becomes noticeable at heading time when smutted heads emerge from the boot (fig. 1, *A*). Hard, black masses of smut, each covered with a grayish membrane, are found in place of kernels in the affected heads. Each smutted head contains millions of tiny spores. The membranes covering the spore masses begin to split a few days after the diseased heads emerge, and the spores gradually spread to the developing seed in healthy heads while the grain is in the field. Further spread of the spores occurs in threshing. Some spores lie dormant on the surface of the seed. Others are carried under the hulls or send slender infection threads beneath the hulls before or after threshing. These produce most of the infection. The barley seedling becomes infected between germination and emergence from the soil. The highest percentage of infection occurs at soil temperatures of 50° to 70° F. during this period. Mild temperatures for 2 to 4 weeks after the seedlings emerge favor later smut development. More smut develops in plants grown in acid soil than in those grown in neutral or alkaline soil.

Control

Covered smut may be controlled by treating the seed with an organic mercury fungicide. See control measure C, treatments 1 to 9, pp. 22–28.

NIGRA LOOSE SMUT

Nigra loose smut causes an average annual loss of a million bushels of barley in the United States. It was first distinguished from nuda loose smut in this country in 1932

FIGURE 1.—Two smuts of barley: *A*, Covered smut; *B*, nuda loose smut; *C*, healthy head.

and has since been recognized in many other countries. Usually the disease is first noticed at heading time when the dark, smutted heads appear (fig. 2). Each head contains millions of loosely held, dark-brown, microscopic spores that are scattered by the wind chiefly during the period when the healthy heads are in bloom. Some of the spores come in contact with the flowers and the young developing seeds of healthy heads. Infection of the seed takes place in much the same manner as described for covered smut. Depending upon moisture and temperature conditions, the spores may lie dormant or they may germinate and send infection threads beneath the seed hulls. These threads infect the young seedling as it grows underground from the seed to the surface of the soil, as described for covered smut. Spores on the surface of the seed also may cause infection of the plant. Temperatures of 60° to 70° F. and relatively dry soil during the period of emergence are most favorable to infection. As with covered smut, mild weather conditions for 2 to 4 weeks after the seedlings appear result in a higher percentage of smut than do constant low temperatures.

Control

The seed treatments that control covered smut also control the nigra loose smut. See control measure C, treatments 1 to 9, pp. 22–28.

NUDA LOOSE SMUT

Nuda loose smut closely resembles the nigra loose smut in amount of damage to the barley plant, in appearance of the smutted heads, and in the spread of its spores during the flowering of healthy heads (fig. 1, *B*). An important difference occurs, however, after the nuda spores reach the barley flowers. The spores normally germinate at once and develop long, slender infection threads that enter and grow deeply within the young developing seeds. Unlike covered smut and nigra loose smut, which are carried on or in the shallow layers near the surface of the seed, the nuda smut fungus becomes so deeply embedded within the germ or embryo of the barley kernel that it cannot be controlled by treating the seed with easily applied surface disinfectants. Both the nuda and nigra loose smuts are widely distributed in humid and subhumid areas, but are less common in dry areas.

Since the two loose smuts of barley are so similar in appearance, but so different in their response to control by easily applied seed treatments, it is highly desirable to have a positive method of determining which of these smuts is attacking the barley. In the field the fully emerged heads of the nuda smut usually are lighter brown than those of the nigra smut, but this difference is hardly sufficient for positive identification. Each of the species may be readily identified, however, by a laboratory test of spore germination. Growers who wish to learn which species of loose smut is attacking their barley should send several smutted heads for identification to their State agricultural college or experiment station, or to the Plant Industry Station at Beltsville, Md.

Control

Losses due to nuda loose smut can best be avoided by sowing only certified smut-free seed, or seed of varieties known to be resistant to nuda loose smut. If such seed is not available, seed treatment by the hot-water or some other effective soaking method is the only alternative. Nuda loose smut cannot be controlled by the common chemical seed treatments because the fungus is carried in the embryo or seed germ. Any chemical that will kill the smut will also kill the seed germ. How-

FIGURE 2.—Nigra loose smut: *A*, Healthy head of barley; *B*, a newly emerged head of nigra loose smut; *C–F*, four older heads of nigra loose smut in various stages of disintegration.

ever, this smut can be controlled by the hot-water treatment because the barley seed germ can endure a temperature slightly higher than that required to kill the smut fungus within it.

The hot-water treatment, however, is very exacting and must be carried out with extreme care as to temperature and length of treatment. It consists of three main steps:

1. The seed is placed in loosely woven burlap sacks, only half-filled and tied at the top. It is then soaked for **5 hours** in water that is near room temperature (70° F.). The sacks should lie on their sides and should be turned or rolled about every half hour to prevent caking of the swelling seed.

2. The seed is then removed from the water, drained for about 1 minute, and placed in a tempering bath at 120° F. for about 1 minute. It is then placed in water held at **exactly 126° F.** for **exactly 11 minutes.** The water must be kept at this temperature during the treating period by adding steam or hot water heated above 126° F. The water should be stirred to keep the temperature uniform, and the sacks should be rolled as in the first bath to insure an even penetration of the heat into the mass of seed.

3. After the 11-minute soak, the seed should be plunged into cold water to stop the action of the hot-water treatment and avoid injury to the seed. If a cold-water dip is not convenient, the seed should be raked out promptly in a thin layer so that it will cool rapidly. It is then allowed to dry enough so that it can be sown.

Surface-dry seed will run through the drill and may be sown if the soil is moist enough to insure prompt growth. If such seed is sown, the drill should be set at a higher seeding rate to allow for the swollen condition of the grain. It is safer to sow the seed after it has been thoroughly dried. Seed that is only surface-dry contains enough moisture to induce germination. If such seed is sown in dry soil, the stand may be severely reduced.

Other time periods and water temperatures have been recommended for treating barley seed, but they are less dependable than the above schedule. Poor control of nuda loose smut may result at times because the water used for the long presoak is too cold. At a low temperature the seed does not absorb enough water to make the hot-water treatment effective. To insure control, therefore, the temperature of the presoak should be kept at about 70° F.

The hot-water treatment of seed for the entire crop is not recommended. The treatment is difficult and usually reduces seed germination, particularly where the seedcoats have been broken in threshing. If seed from smut-free fields cannot be obtained it is best to treat only enough seed for sowing a seed plot that is isolated from fields sown to untreated barley. This plot will furnish smut-free seed for the next year's crop. Successive crops, if fields are properly isolated, may remain relatively free from loose smut, so that further seed treatment may not be necessary for several years. However, infection of the seed may take place if the treatment did not kill all the seed-borne loose smut, or if loose smut is present in nearby fields.

Community seed-treating plants for applying the hot-water treatment have been operating satisfactorily in several States. Usually the plants are managed by the county agricultural agent or by cooperating farmers. A number of large, relatively smut-free areas have been established through the use of such treated seed and of seed from crops produced from the

FIGURE 3.—Stem rust of barley: *A*, Rust pustules on barley neck; *B*, on leaf sheath; *C*, on stem. (Courtesy of D. R. Shepherd, Minneapolis, Minn.)

treated seed. The beneficial effects of the treatment are made more lasting in this way as the fields within the smut-free areas are mutually protected from infection.

Nuda loose smut has been prevented experimentally by soaking the infected seed in water at room temperature (72° to 77° F.) for 56 to 64 hours. This treatment causes severe reductions in stand in some varieties, but it is less difficult and exacting to apply than the hot-water treatment.

Loose smut has been prevented also by soaking the infected seed in water at 72° to 75° F. for about 10 hours and then in a 0.2-percent suspension of Spergon for 48 hours. This treatment injures the seed more severely than the treatment by water alone, but it prevents fermentation.

RUSTS OF BARLEY

Two rusts attack barley in the United States. They are stem rust and leaf rust.

STEM RUST

Stem rust sometimes injures barley seriously. It is caused by the same stem-rust fungus that attacks wheat and rye. The disease is recognized by pustules that break through the surface of the stems, leaves, and leaf sheaths, and often the chaff and beards (fig. 3). In severe attacks the kernels are badly shriveled as a result of damage to the plants, and the rusted stems turn brown, become dry and brittle, and soon break over.

The stem-rust fungus has a complicated life history. In the northern half of the United States the rust overwinters on the stubble and straw of barley, wheat, and rye as black, thick-walled, cold-resistant spores. These spores germinate in the spring and produce secondary spores that cannot infect barley but do infect the leaves of the common European barberry bush. On this bush the rust produces spores that cannot reinfect the barberry but can infect barley plants, and produce the red-rust stage. This stage may persist on barley during the spring and summer and may produce successive crops of red spores every 10 to 14 days until growing conditions become unfavorable. Then the over-wintering black spores again appear.

In the Southern States and northern Mexico the rust lives continuously in the red-rust stage. After the barley is harvested the rust continues to form spores on volunteer grains and wild grasses. These red spores and those blown

down from the North in late summer and early fall infect fall-sown barley. If weather conditions are favorable in the spring, the rust multiplies and the spores are carried northward by the wind with the advance of the crop season. Thus a heavy rust epidemic in the South is a threat to barley fields in the North.

Control

The use of early varieties, and such cultural practices as early seeding and the use of phosphate fertilizers, which hasten ripening, may help the barley to escape rust. However, they do not prevent damage when infection is severe. Late seeding delays ripening and is likely to increase the rust damage because it provides a longer period for the development of the rust. Heavy applications of barnyard manure or nitrogen fertilizer also may delay ripening and may produce a heavy vegetative growth that retains moisture and favors the development of rust.

Extensive trials have shown that the stem and leaf rusts of wheat, and presumably those of other cereals, can be prevented by dusting the fields with sulfur or certain other fungicides. At present, however, this method is too costly to be practicable.

The extensive eradication of the common barberry has greatly reduced damage from stem rust. The discovery that rust may hybridize on barberry bushes and thus produce new and often more virulent races of rust is an additional reason for continuing this eradication campaign.

Breeding for varietal resistance to rusts is one of the most promising methods for controlling all rusts of small grains. The stem-rust-resistant variety, Kindred, is now grown more extensively for use in malting than any other variety in the principal barley-producing area of the United States. Other commercially grown varieties resistant to stem rust are Peatland, Mars, Plains, Feebar, and Moore. The Goliad variety released in 1953 is resistant to both stem and leaf rusts. See control measure A, page 20.

LEAF RUST

Barley leaf rust is seldom important in areas where spring barley is grown, but sometimes is destructive locally to winter barley. Occasionally, leaf rust becomes so severe that the yield and the quality of grain are appreciably reduced.

The pustules of the summer stage of leaf rust that appear on the leaves and leaf sheaths of the barley plants are small, round, and yellow or yellowish brown (fig. 4). The rust survives the winter in this stage in the southern winter-barley regions, and spreads northward with the advance of spring. Infection in the northern barley areas frequently is not evident until late in the spring or early summer.

Control

The use of resistant varieties is the only practicable method of control. Several such varieties are available. As noted above, the variety Goliad is resistant to both leaf and stem rust. See control measure A, page 20.

POWDERY MILDEW

Powdery mildew is more important on barley than on other cereal crops. When severe, it may reduce yields up to 25 percent or more. Like many diseases, it reduces or impairs the green leaf tissue that the plants need for the manufacture of sugars and starches. When damage from powdery mildew or other leaf blights occurs early, the plants produce fewer heads and fewer kernels per head. When attacks begin later in the life of the plant, the size and the weight of the kernels are re-

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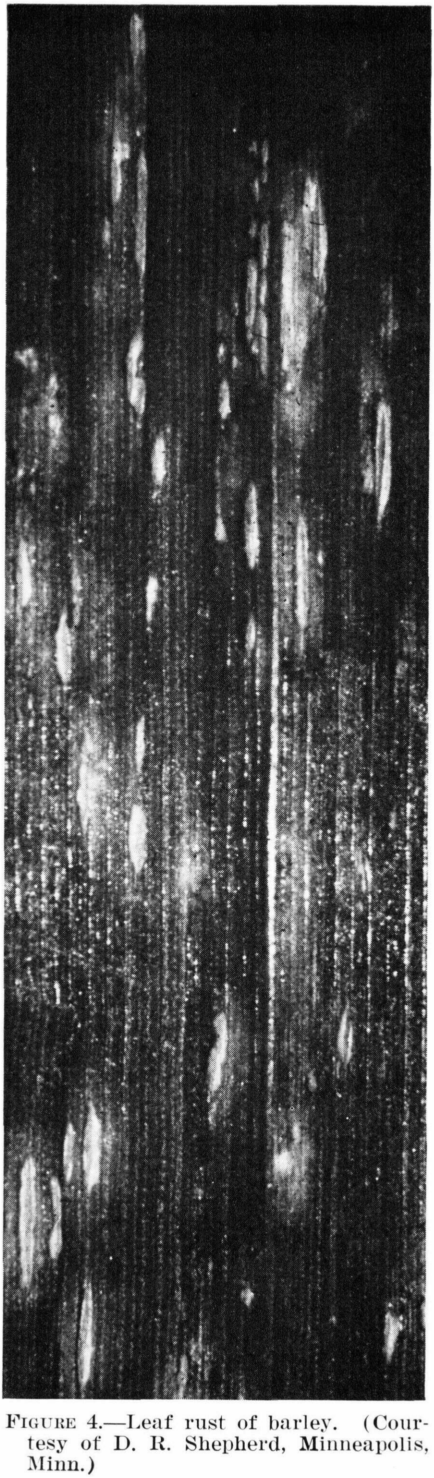


FIGURE 4.—Leaf rust of barley. (Courtesy of D. R. Shepherd, Minneapolis, Minn.)

duced. Powdery mildew is particularly troublesome in the Atlantic and Southeastern States where winter barleys, for the most part, are grown. Occasionally it causes serious losses in the North Central and Pacific Coast States.

The first indications of infection are small, white or light-gray spots of cottony threads on the upper surface of the leaves. The spots enlarge, darken, and become powdery with age as they produce millions of spores to infect other plants. Eventually they may involve large areas of the leaf (fig. 5). A yellowing, followed by browning and gradual drying of the leaf usually accompanies this process. The mildew makes its main growth on the upper surface of the leaves, more rarely on the under surface, and in severe attacks may be found on stems, glumes, and awns. As the plant approaches maturity, tiny, black, reproductive bodies (perithecia) of the fungus develop in the infected areas. These may help the disease to overwinter.

Control

Mildew is more severe on tender, rank-growing plants. Thick seeding, heavy application of nitrogen fertilizer, and other factors that promote a heavy, leafy growth, therefore, should be avoided. Mildew can be controlled by dusting the plants with sulfur, but this method is not economically practical. Control through the use of resistant varieties, therefore, is recommended. See control measure A, page 20.

SCAB

Scab, also known as Fusarium head blight, sometimes causes severe damage to barley, wheat, rye, and some grasses. Corn also is attacked. Heavy losses are most common in the eastern and central

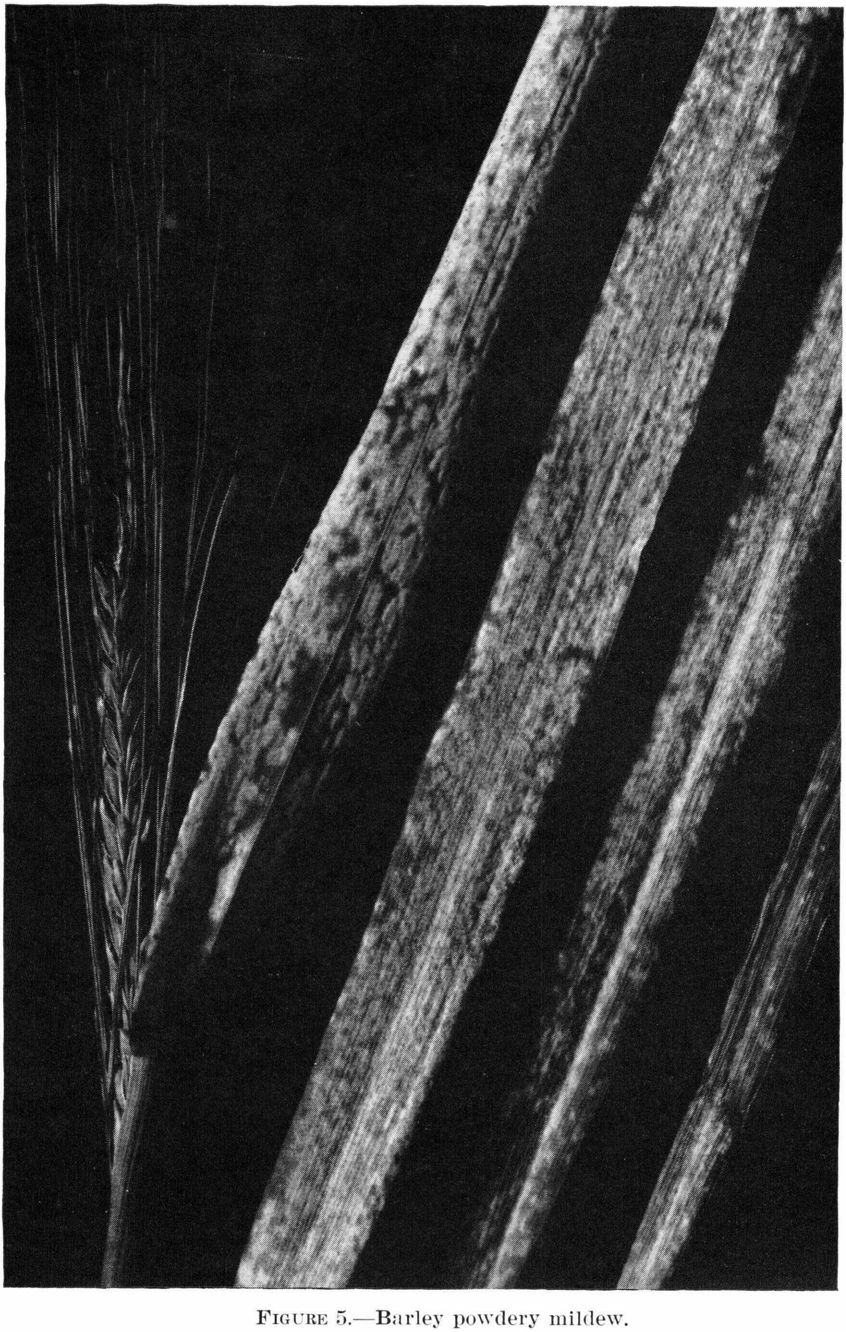


FIGURE 5.—Barley powdery mildew.

FIGURE 6.—Scab of barley: *A*, Healthy head; *B*, and *C*, moderately infected heads; *D*, severely infected head showing fruiting bodies (perithecia). (Courtesy of J. G. Dickson, University of Wisconsin.)

Corn Belt. The scab fungus also causes a foot rot and seedling blight of barley.

The scab head blight develops in warm, humid, weather during the formation and ripening of the kernels. Infection begins in the flowers and frequently spreads to other parts of the head. In barley the diseased area turns light brown. A pink, moldy growth often develops around the base of the infected flower (fig. 6), and black fruiting bodies (perithecia) may be found on the glumes.

Kernels of diseased heads are grayish brown and light in weight. The interior of the kernels becomes floury and discolored, and new compounds are formed that cause acute vomiting when the grain is eaten by hogs, dogs, or man. Sheep, cattle, and mature poultry, however, are not affected, and scabby barley may be fed to these animals, since it is impossible to separate all scabby barley grain from the healthy grain.

The scab fungus overwinters on barley seed (fig. 7) and in plant residues of barley, corn, and other affected crops of the previous season. Infected seed, when sown, produces infected seedlings. Spores borne on diseased plant litter, such as corn stubble, also may cause seedling infection and later may cause infection of flowers of the young barley heads. The crown tissues of the barley plants are invaded largely by fungus threads from diseased plant residue in the soil.

Control

The use of clean seed and treatment of diseased seed with an organic mercury fungicide (see control measure C, treatments 1 to 9, pp. 22–28) are effective in controlling seedling infection. Sanitation, crop rotation, and early seeding help to reduce crown infection and head blight. Soil preparation, that completely covers residues of previous crops of barley, wheat, and corn, helps to reduce the spread of fungus spores that lead to head blight.

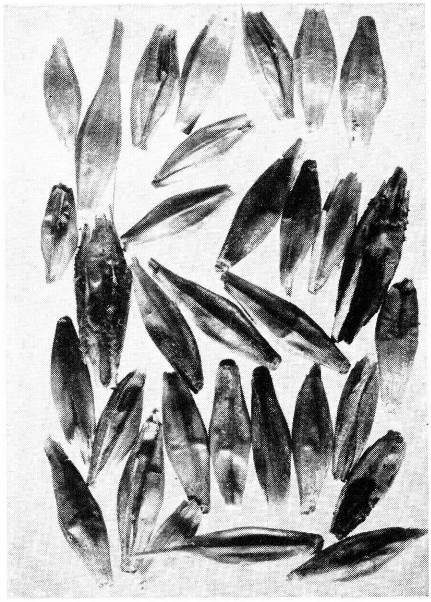


FIGURE 7.—Scab of barley: Infected kernels showing discoloration and, on some, the fruiting bodies of the fungus. (Courtesy of J. G. Dickson, University of Wisconsin.)

STRIPE DISEASE

Stripe disease causes considerable damage in California and in the South Central States but is relatively unimportant in the North Central States.

The disease originates from infected seed and first appears as long, pale-green stripes on the leaves (fig. 8). As the leaves reach full development these stripes turn brown, and the leaves may split along the stripes. All the leaves of diseased plants usually are affected. Diseased plants are stunted and usually do not head or produce seed.

Spores of the fungus produced on striped leaves are blown about the field during and after the flowering

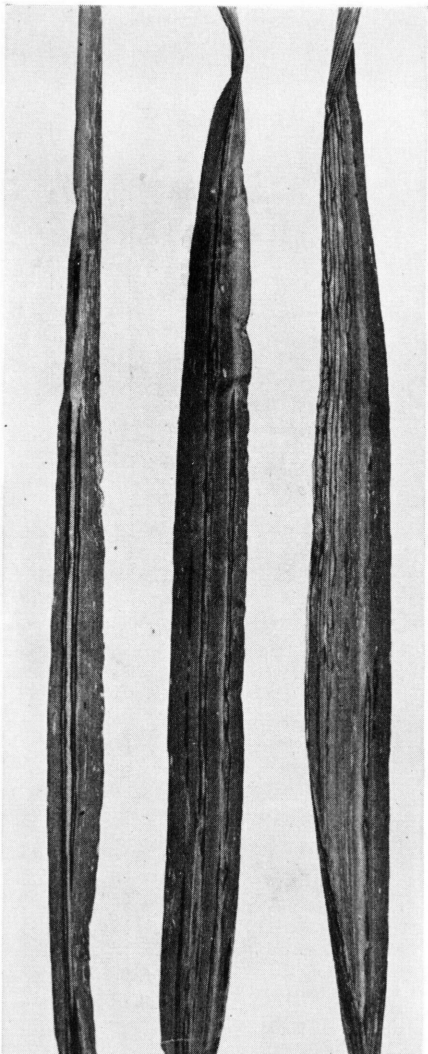


FIGURE 8.—Barley stripe disease: Infected leaves showing the stripes along the leaf veins.

period. Kernels of healthy heads become infected by these windblown spores. Infected kernels cannot be distinguished from uninfected kernels as the disease is not apparent in the dormant seed.

Control

Resistant varieties, if available, offer the best means of control. Seed treatment with an effective organic mercury fungicide kills the seedborne infection. (Control measure C, treatments 1 to 9, pp. 22–28.

SPOT BLOTCH

Spot blotch is widespread and may cause severe damage. The causal fungus may be seedborne or present in the soil. It attacks barley, wheat, rye, and many grasses. All parts of the barley plant are affected. On the seedlings, dark-brown to black discolorations appear on the blade or sheath of the first leaf and the seedling may be killed. The roots of diseased seedlings show darkened areas and rotting. Dark-brown spots appear on the leaves. The spots fuse to form blotches that may cover large areas of the leaf blade (fig. 9). Heavily infected leaves dry out and mature early. Numerous dark-brown spots may appear on the germ end of diseased kernels (fig. 10). This condition is commonly called black point. Grain containing 5 percent or more of black point kernels brings a lower price on the market. The fungus overwinters in the seed and on crop residue.

Control

Resistant varieties and seed treatment offer the best means of control. (Control measure C, treatments 1 to 9, pp. 22–28.) Sanitation and crop rotation are important, but in the spring-grain area crop rotation is not effective because a large percentage of the acreage is given to other grains and grasses that also harbor the disease.

NET BLOTCH

Net blotch is very common, especially when cool weather prevails

FIGURE 9.—Barley spot blotch: Barley leaves showing infected areas, some of which have fused. (Courtesy of T. T. Hebert, Raleigh, N. C.)

during much of the growing period. Usually the disease is of minor importance, but under conditions favorable for its development it may cause considerable damage. Brown areas appear on the leaves from the seedling stage until maturity. These areas show a network of dark-brown lines within an area of lighter brown. The netted areas enlarge and fuse in the course of the growing season (fig. 11). Spores produced on the diseased leaves are blown to other leaves, and repeated secondary infection spreads the net blotch to other plants in the course of their growth. The fungus overwinters in infected seed and on old straw and stubble.

Control

Resistant varieties, sanitation, and crop rotation are important in control of net blotch. Barley sown on or near fields with diseased stubble on the surface may become heavily infected. Seed treatment with mercury dusts kills the fungus carried in the seed. (Control measures A, p. 20 and C, p. 22; treatments 1 to 9, pp. 26–28.)

BACTERIAL LEAF BLIGHT

Bacterial leaf blight is widely distributed, especially in the spring barley areas. Usually it is of minor importance but occasional severe outbreaks on susceptible varieties may result in reduced yields. Diseased plants develop irregular,

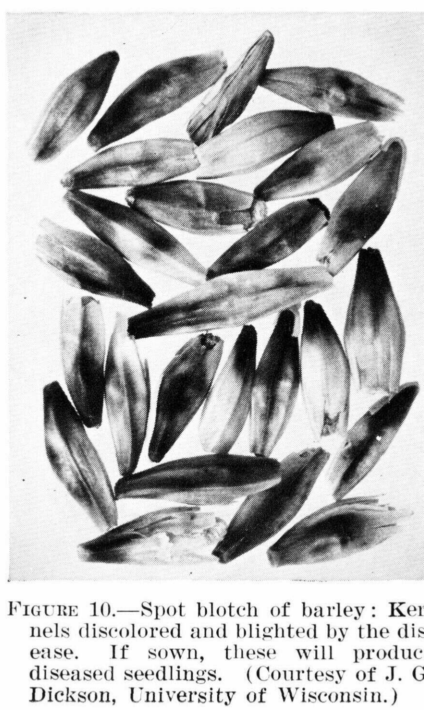


FIGURE 10.—Spot blotch of barley: Kernels discolored and blighted by the disease. If sown, these will produce diseased seedlings. (Courtesy of J. G. Dickson, University of Wisconsin.)

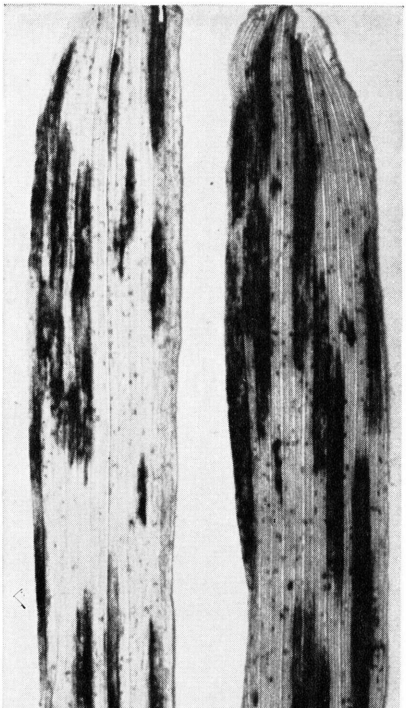


FIGURE 11.—Barley net blotch.

narrow, glossy-surfaced stripes on the leaves. The stripes frequently show water-soaked areas ranging in color from light yellow to dark brown. The affected leaf areas give off small drops, or a thin film, of a white sticky bacterial substance which dries to a thin flaky layer. Similar diseased areas may develop on the leaf sheaths and floral parts (fig. 12). Severe late attacks result in blighting of the head.

The disease is caused by bacteria. It is favored by wet weather, and is spread by rain and insects. The bacteria persist from season to season on the seed, in crop residue, and in the soil.

Control

Crop rotation and treatment of the seed with organic-mercury fungicides help in control. (Control measure C, treatments 1 to 9, pp. 22–28.) Occasional outbreaks of the disease occur, however, regardless of control measures. Some barley varieties display more resistance than others.

SCALD

Scald is important chiefly in California and in the winter barley areas of the mideastern, southeastern, and extreme southwestern parts of the United States. This disease attacks also rye and certain grasses. Losses in yield up to 20 percent have resulted from severe attacks. Scald appears as oval- or lens-shaped spots, which at first are water-soaked and gray-green. Later the spots appear as pale or white central areas surrounded by irregular rings of brown tissue (fig. 13). The disease is spread during the growing season by spores produced on diseased leaves. The fungus overwinters on infected dead leaves and probably on other crop residue. From this overwintering fungus the disease spreads to barley seedlings the following spring. A cool growing season favors the disease.

Control

Resistant varieties, crop rotation, and turning under the crop residue offer the best means of control.

FIGURE 12.—Bacterial leaf blight of barley: Infected leaves showing typical lesions and bacterial exudate.

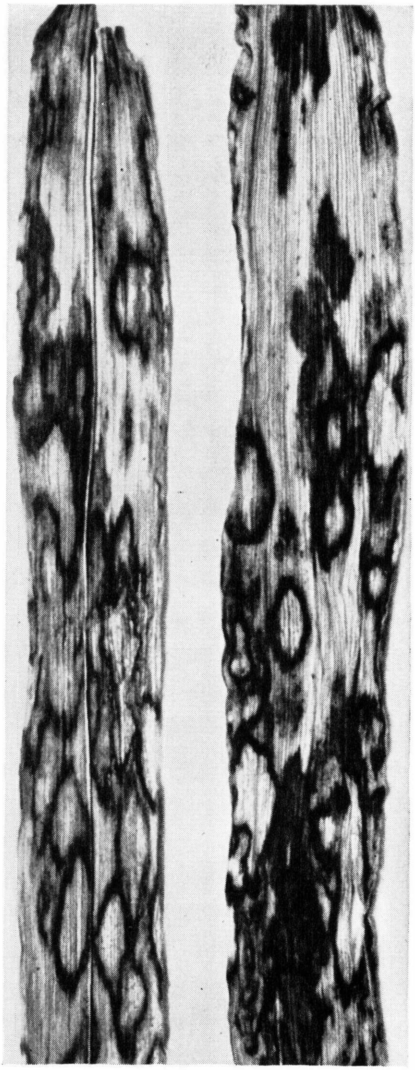


FIGURE 13.—Barley scald: Leaves showing areas infected by the scald fungus.

ERGOT

Ergot attacks barley and other cereals, and many wild and cultivated grasses. It is usually more severe on rye than on barley and wheat but certain varieties of barley and wheat may be heavily infected.

The disease is readily recognized by the hornlike ergot bodies (sclerotia) in the barley heads (fig. 14). These sclerotia fall to the ground at harvest time or are harvested with the grain. The sclerotia that overwinter in the soil germinate in the spring by sending up long, slender stemlike "stipes," which produce spores (ascospores) at their tips at about the time the barley is in flower. These spores are carried by the wind to the barley flowers, which become infected. The fungus then produces another type of spore in the barley flowers along with a sugary liquid or "honeydew." Insects are attracted by and feed on this honeydew and thus carry the spores to other barley heads, which in turn become infected. Later the fungus forms ergot sclerotia in the barley heads (fig. 14).

Ergot sclerotia contain a poisonous material that makes ergot-infested seed highly undesirable for feed or flour. In the United States grain is classed as "ergoty" when it contains more than 0.3 percent of ergot sclerotia by weight. In the past, such grain was discounted heavily. This low tolerance of ergot is necessary because of the danger to animals and humans from eating the poisonous ergot. Serious diseases of horses, cattle, and humans are caused by eating quantities of grain, straw, or flour containing ergot. Extract of ergot is used in making certain obstetrical medicines, and sound sclerotia at certain times bring high prices.

Control

The ergot fungus spreads readily to barley from many weedy grasses in or near the barley field. Crop rotation and the removal or cutting of such grasses may reduce the disease. Modern seed-cleaning machinery removes the ergot bodies from the seed grain. The sclerotia may be separated from the sound barley also by immersing the ergot-infested seed in a 20-percent solution of common salt made by dissolving 40 pounds of salt in 25 gallons of water. The ergot and light

FIGURE 14.—Ergot of Barley: *A*, Healthy heads; *B*, infected heads with ergot sclerotia replacing some kernels. (Courtesy of J. G. Dickson, University of Wisconsin.)

kernels will float and may be skimmed off. The seed must be rinsed in fresh water to remove the salt. Fortunately the ergot bodies do not remain viable longer than 1 year, and hence old seed containing ergot does not carry over the disease.

VIRUS DISEASES

Most plant viruses cause injury through impairing or destroying chlorophyll, the important substance that enables the green leaf to manufacture sugars and starches. Some viruses merely stunt or deform the plants, while others give no indication of their presence in the plants. Barley is susceptible to two virus diseases. They are known as stripe mosaic and yellow dwarf.

STRIPE MOSAIC[1]

Stripe mosaic symptoms have been observed in barley for many years and until 1950 were thought to be due to some physiologic disturbance in the plants. In 1950 it was found to be caused by a seedborne virus. So far as is known, this is the only virus that is transmitted through the seeds of plants belonging to the grass family. The disease occurs to some extent in all barley-producing regions in the United States and Canada. Experiments have shown that it may cause a considerable reduction in grain yields, and in some spring barley areas it is a serious factor in barley production.

The symptoms of stripe mosaic vary with the barley variety, the strain of the virus, and seasonal conditions. The virulent strains of the virus may cause brown stripes in the leaves (fig. 15) of Chevron and several other varieties of barley, but the most frequent symptoms observed are short-to-long, bleached, yellow or light-green stripes, light-green to yellow

[1] Prepared by H. H. McKinney, who identified the disease in 1951.

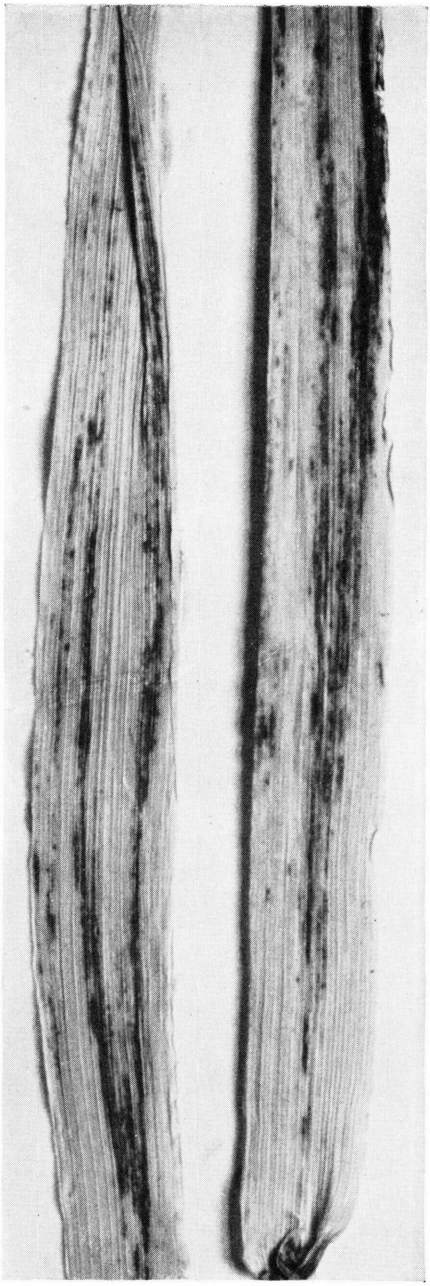


FIGURE 15.—Stripe mosaic of barley: Leaves showing the typical short, mottled lines caused by the virus.

mottling, and sometimes almost a complete yellowing of the leaves. Plants become severely stunted when much of the green chlorophyll in the leaves is destroyed.

The less virulent strains of the virus rarely cause brown stripes, but produce bleached and yellow patterns somewhat like those caused by the virulent strain, but of a milder degree, as little of the chlorophyll is destroyed. Sometimes symptoms do not appear in the upper 3 or 4 leaves although the virus is present in them.

Some varieties of barley have shown signs of resistance to stripe mosaic, and it is possible that completely resistant varieties will be developed by selection.

Healthy plants can become infected when they are whipped against diseased plants by wind currents and sometimes when they receive pollen from diseased plants. Whether or not insects can transmit stripe mosaic virus from diseased to healthy plants is not known.

Control

Since the virus is carried from crop to crop in the seed, it is desirable to avoid sowing seed that is infected, as there is no known treatment that will kill the virus without killing the seed. Seed samples can be tested for the presence of virus infection by sowing them in a greenhouse kept at temperatures near 80° F. under good light conditions during early seedling development. Most of the seedlings from infected seed will show symptoms in the first to the third leaf. If these infected seedlings are discarded as soon as observed, the remaining seedlings may serve as an initial source for stocks of virus-free seed.

YELLOW DWARF

The yellow dwarf virus disease of barley was first observed in California in 1947, but its cause was not determined until 1951 when a 10-percent loss to the barley crop was suffered in that State. This virus causes a brilliant golden yellowing

FIGURE 16.—Yellow dwarf virus on Mariout barley: *A*, Plant infected in early tillering stage; *B*, plant infected in jointing stage; *C*, healthy plant. (Courtesy of B. R. Houston, Davis, Calif.)

of the leaves and moderate-to-severe stunting of the plants (fig. 16). The younger the plants are at the time they become infected, the more severe is the infection. Symptoms vary somewhat with the variety of barley, but yellowing of the leaves is always the first indication that the plant is infected. The growth of the root system also is retarded.

The disease is spread from plant to plant by five different species of aphids. It is not transmitted through seed or soil. Wheat and oats also are susceptible.

Control

The severity of the disease is somewhat decreased by sowing early so that the plants are fairly well developed by the time the weather is warm enough for aphid activity. Complete control of the aphids will, of course, eliminate the disease. The eventual control of the disease lies in the development of varieties resistant to it.

ROOT ROTS

The term "root rots" is here applied to all diseases that affect the roots, crown, and other basal parts of the plants. The root rots of barley and other small grains are among the least evident diseases, but they can be very damaging. Some are present probably every year in all fields of cereals in the United States. At times they cause considerable losses in barley, oats, and wheat. Two destructive epidemics of barley root rots occurred in the upper Mississippi Valley in

1943 and 1944. Barley production in Minnesota dropped from about 50 million bushels to less than 13 million. Yields per acre in some areas dropped more than 30 percent.

The various types of root rot have been given such names as seedling blight, take-all, root rot, basal stem rot, and foot rot. Some root rots are easily recognized, but others are difficult or impossible to identify except by examination in the laboratory.

The root rot fungi attack all underground parts of the plants and may cause seedling blight, stunting of the plants, yellowing and bleaching of the foliage, discoloration of the roots and the bases of the stems, and premature death of the plants (fig. 17, *A*). The same organisms may infect also the upper parts of the plants and cause head blight, leaf lesions, and rotting of the nodes. Barley plants are subject to attack by these fungi from the time the seeds germinate until the plants are mature.

The root-rotting fungi tend to multiply in the soil when susceptible crops are grown year after year. Their prevalence therefore can be greatly reduced by crop rotation and other cultural practices. Attacks by the root-rotting fungi are favored by various conditions unfavorable to the development of the barley plants. Seedling blights and root rots generally are most severe at relatively high temperatures. Rusts and other leaf diseases, insect damage, and winter injury to fall-sown grain may increase susceptibility to root rots.

Barley seed produced in the more humid parts of the United States is commonly infected by certain bacteria and fungi including root-rotting fungi. When such seed is sown, seedling blight, root rot, basal stem rot, and lowered yields often result. Cracking and chipping of the seedcoats during threshing permit soil-inhabiting fungi to invade the seed, and they may cause it to rot before it can germinate, especially when conditions are unfavorable to germination.

Control

Root rots can be greatly reduced by good agricultural practices. Sound seed of recommended varieties should be treated with an effective mercurial fungicide (see control measure C, treatments 1 to 9, pp. 22–28) to kill the harmful fungi and bacteria on the seed, and to protect the seedlings against the root rot fungi present in the soil. Also, the seed should be sown only deep enough to provide adequate moisture for germination. A good crop rotation must be followed. The seedbeds should be well prepared and the proper fertilizer applied. Only recommended resistant varieties should be grown. Good farming is the best method of reducing losses due to root rots of barley and other cereals.

CONTROL MEASURES

Barley diseases may be combated in three ways:

A. By growing disease-resistant varieties

Where disease control by the use of resistant varieties is advised, the grower should consult the county agricultural agent or the State agricultural experiment station for the latest recommendations because the list of approved resistant varieties is constantly changing. New diseases or new races of old diseases may come into a locality at any time, and may attack the barley varieties being grown there, so that a change to other varieties may be desirable.

B. By following certain cultural practices

Sanitation and approved cultural practices for the control of some barley diseases are discussed in the preceding pages. These include

FIGURE 17.—Crown and root rot of barley caused by *Helminthosporium sativum*: *A*, Wisconsin Barbless, susceptible and severely infected; *B*, Moore, resistant and uninjured. (Courtesy of J. G. Dickson, University of Wisconsin.)

FIGURE 18.—An oil-drum mixer for applying fungicides to seed. Its capacity is 20 to 30 bushels per hour. (Designed by R. S. Kirby, Pennsylvania State College.)

such generally recommended measures as plowing under stubble and other plant litter that may enable disease organisms to live over from one season to the next. Crop rotation, proper land preparation, and time of seeding also may be important factors in disease control.

C. By treating seed

Seed treatment is effective mostly against diseases that are carried over from one year to the next on or in the seed. Some of the better chemical seed treatments, however, also protect the germinating seed to some extent against injurious soilborne organisms that cause seed rot, damping off, and seedling blight. These chemical fungicides usually contain mercury and are poisonous. Three barley diseases—stripe disease, covered smut, and nigra loose smut—can be completely prevented by effective chemical seed treatments. These treatments also control the seedborne phases of several other barley diseases, such as bacterial blight, scab, net blotch, and spot blotch, but they do not prevent the spread of these diseases by airborne spores from neighboring fields. Other diseases such as the rusts, mildews, scald, and some virus diseases are not affected in any way by seed treatment.

The nuda loose smut is controlled by hot-water and long-soak seed treatments but not by common chemical seed treatments. The hot-water treatment also controls other seedborne diseases, but does not protect the seed against disease-causing fungi in the soil, as do the chemical treatments.

Chemical fungicides are applied to seed in several forms and by several methods. They are marketed either as dusts or liquids. Fungicidal dusts may be applied to seed either in dust form or as a thick water suspension called a slurry. Small lots of seed may be dusted on the farm by means of a "batch" type of treater such as the oil-drum treater (fig. 18) or the barrel treater

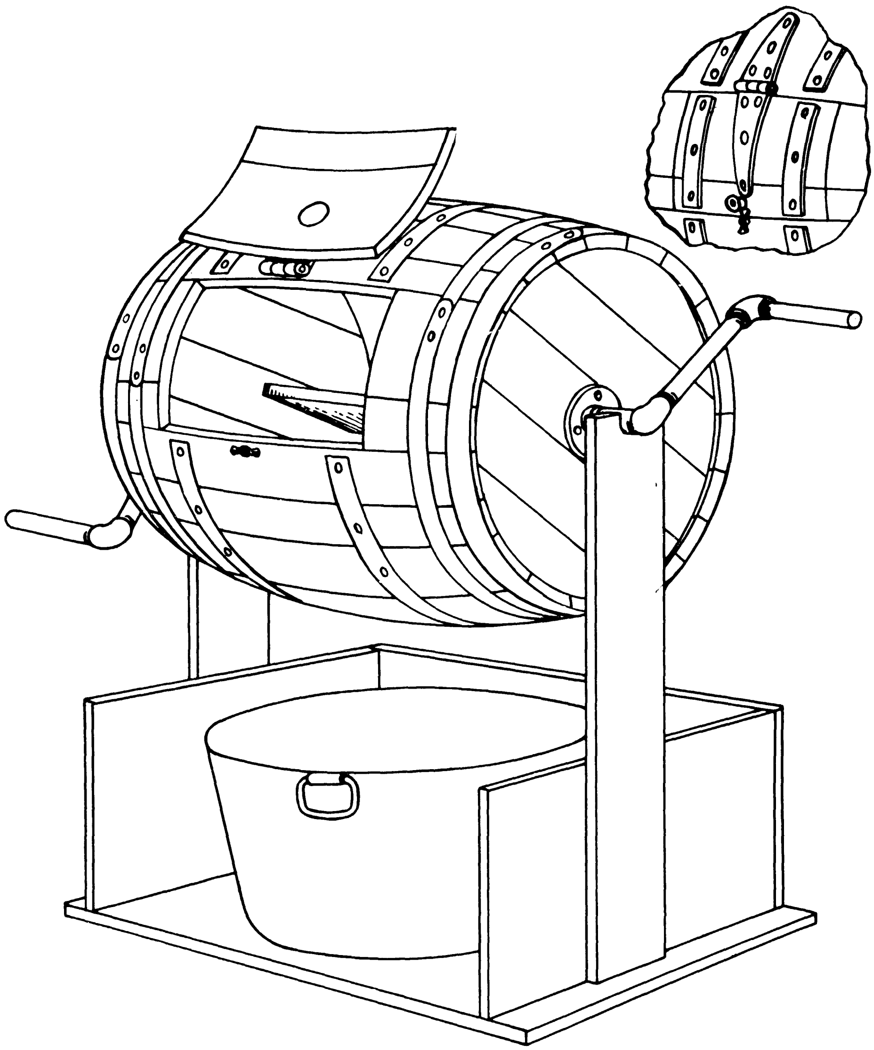


FIGURE 19.—A barrel treater for applying dust fungicides to seed grain. (Designed by the late F. W. Oldenberg, University of Maryland.)

(fig. 19). These treaters will enable two men to treat 20 to 40 bushels of seed per hour.

Volatile dust fungicides, such as those containing mercury, may be applied also in a gravity-type treater (fig. 20). The capacity of a small gravity treater may range from 30 to 60 bushels per hour. Large treaters in commercial seed houses may treat 400 or more bushels per hour.

The chief objection to dust treatments is the discomfort and health hazard caused by the dust in the air during treatment and when handling and sowing the treated seed. This disagreeable feature of applying dust fungicides is largely eliminated when the slurry method is used. A slurry for treating barley seed at the rate of one-half ounce of the fungicide per bushel is made by mixing an effective volatile dust

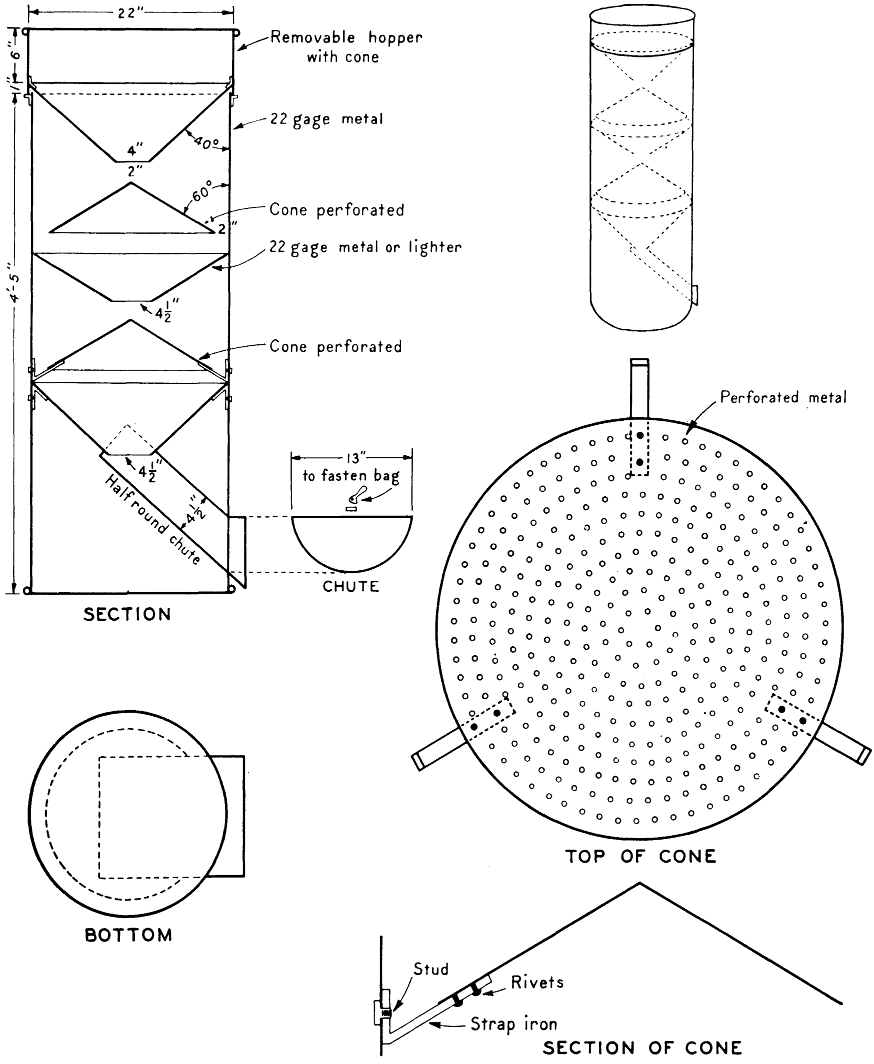


FIGURE 20.—Details for constructing a small gravity-type treater for applying volatile mercurial dusts to seed.

fungicide with water at the rate of 1¼ pounds per gallon. This can be sprinkled over 40 bushels of seed barley spread out on a clean floor in a well-ventilated room. The seed is then shoveled over several times and left in a pile covered with a canvas for from 2 to 7 days, after which it may be sown or stored.

The slurry also may be applied in an oil-drum batch mixer by sprinkling about one-half pint of the slurry over 2 bushels of seed and then mixing it for about 1 minute. The slurry treatment adds less than 1 percent of moisture to the seed so that the treated seed can be stored without drying it after treatment. If a large amount of seed is to be treated, it is best to use one of the special slurry treaters designed for that purpose (figs. 21 and 22). These treaters may be set to apply

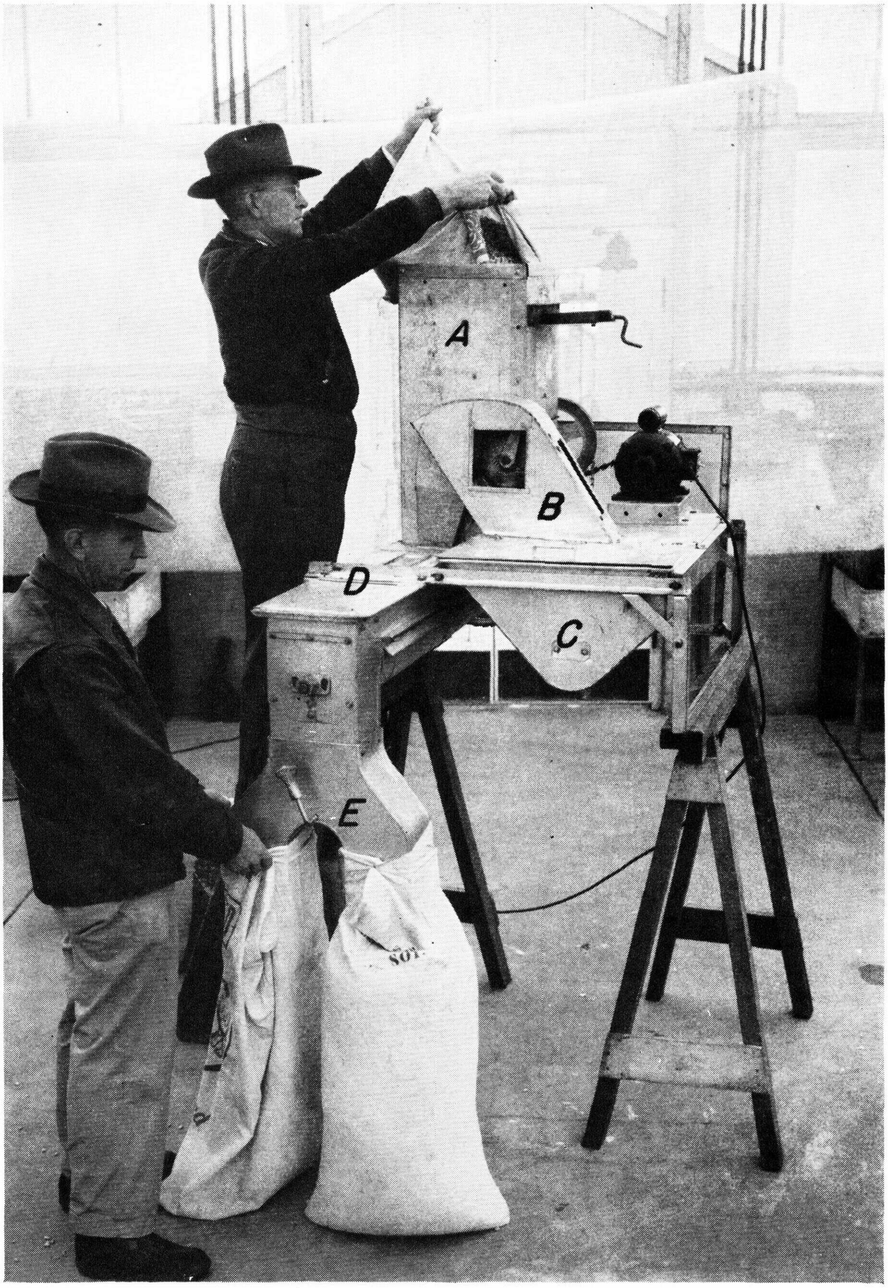


FIGURE 21.—An early type of slurry treater: *A*, Seed hopper; *B*, endless chain of slurry buckets (enclosed); *C*, slurry mixing tank; *D*, seed-slurry mixing chamber; *E*, bagger. In actual operation, seed is fed into hopper by chute. (Designed by G. F. Miles and L. W. Broadbent.)

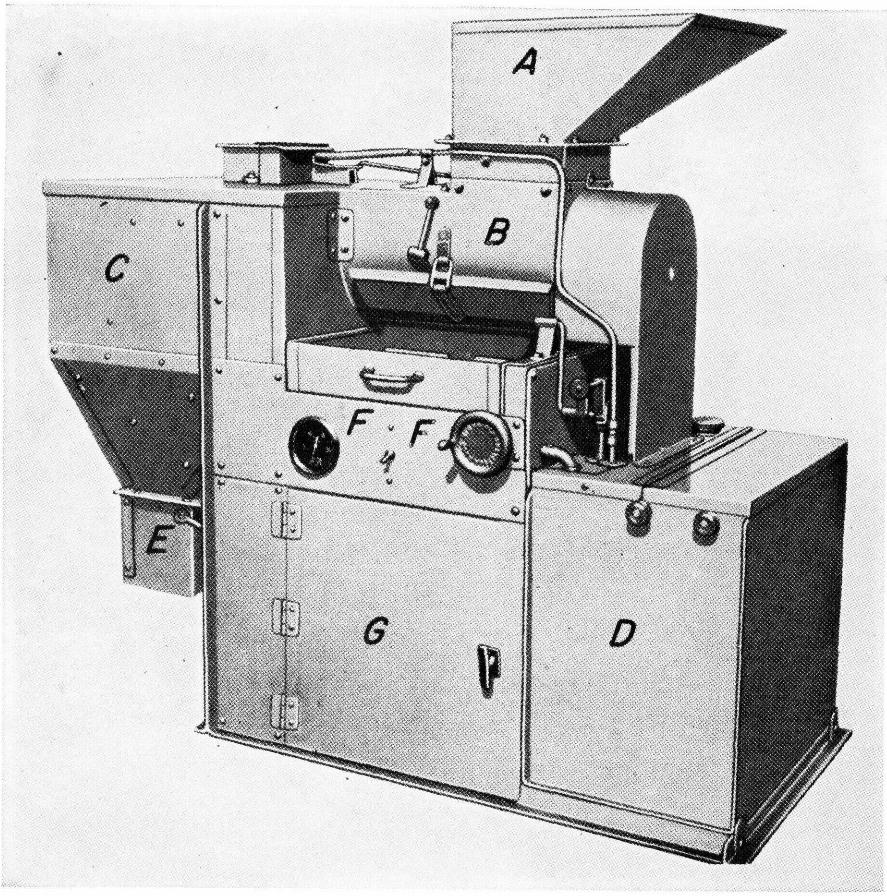


FIGURE 22.—An improved type of slurry treater: *A*, Seed hopper; *B*, seed-flow control chamber; *C*, slurry-application chamber; *D*, slurry tank; *E*, bagger; *F*, controls for rate of application; *G*, motor compartment.

the slurry at any given rate per bushel and are entirely automatic.

Several effective volatile mercurial fungicides in liquid form are now marketed. They may be used either in concentrated form or diluted with water. They may be applied in homemade batch mixers, in slurry treaters, or in special treaters designed for applying them in concentrated form.

Before chemical treatments are applied the barley seed should be thoroughly cleaned to remove weed seeds, light chaffy kernels, smut particles, and other undesirable impurities. It should then be treated with one of the recommended chemical fungicides described below. These treatments have been found effective for controlling certain seedborne diseases of barley. They may also protect the germinating seeds and the young seedlings against certain harmful organisms present in the soil.

Dust and Slurry Treatments

1. Ceresan M (7.7 percent of ethyl mercury *p*-toluene sulfonanilide) may be applied to barley seed at the rate of one-half ounce per bushel as a dust or as a slurry not less than 24 hours or more than 4 weeks before sowing.

2. Ceresan M2X (15.4 percent of ethyl mercury *p*-toluene sulfonanilide) is used as a slurry like Ceresan M, but at only one-fourth ounce per bushel.
3. Agrox (6.7 percent of phenyl mercury urea) is applied at not less than one-half ounce per bushel at least 7 days before sowing. Prolonged storage of treated seed should be avoided as it may reduce germination.
4. Mergamma (1.93 percent of phenyl mercury urea for disease control, and 42 percent of lindane (gamma isomer of BHC) for wireworm control) is applied at 2¼ ounces per bushel when the seeding rate is 1 bushel or slightly less per acre, and at 1¾ ounces per bushel when the seeding rate is 1 to 1½ bushels per acre. The seed should be treated at least 7 days before sowing. Prolonged storage after treatment should be avoided.
5. Puraseed (6.25 percent each of phenyl amino cadmium dilactate and phenyl mercury formamide) may be used as a dust or a slurry at one-half ounce per bushel. It contains 1.8 percent of cadmium and 3.8 percent of mercury.

CAUTION

Ceresan M, Ceresan M2X, Agrox, Puraseed, and Mergamma are poisonous dusts. Care should be taken to avoid breathing the dusts or their fumes. Avoid getting dusts on the skin, especially if the skin is moist, as mercury injury may result. Treat seed in a well-ventilated place. Wear a dust mask over the nose and mouth. Sleeves should be rolled down, and gloves should cover hands and wrists. If slurry gets on the skin wash it off at once with soap and water. Do not use treated seed for feed or food, or store it near feed or food.

Liquid Treatments

6. Panogen is a red liquid seed disinfectant in which the active ingredient, 2.2 percent of methyl mercury dicyan diamide, is dissolved in a carrier that mixes readily with water. It is available as a ready-to-use liquid to be applied at the rate of three-fourths ounce per bushel of barley seed. Panogen can be applied in a homemade oil-drum or barrel treater. An especially designed Panogen treater for convenient and effective application is available for treating larger quantities of seed.

   Panogen may be applied also in a slurry treater, in which case it is necessary to increase the volume by adding 2 pints of Panogen to 1 gallon of water. Panogen mixes readily with water and is without some of the disadvantages of slurry treatments, such as the accumulation of sediment in the tank and in the slurry cups. The dust hazard also is eliminated.

   Panogen-treated seed should be stored for at least 48 hours before sowing.
7. Setrete (7 percent of phenyl mercury ammonium acetate) is a red mercurial liquid that is applied to barley seed at the rate of one-half ounce per bushel, preferably in a slurry treater, although it is a liquid and not a slurry. It may be applied also in a homemade oil-drum treater. Mix 1¼ pints of Setrete in a gallon of water. This amount will treat 32 bushels. Sprinkle 110 cubic centimeters (about one-fourth pint) of this 5 to 32 mixture over each bushel of seed before it is mixed in the treater. The seed should be treated several days before sowing.

   This material is sold also as Pentrete, Gytrete, and Gallotox.
8. MEMA (11.2 percent of methoxy ethyl mercury acetate) is applied at the rate of one-half ounce per bushel. When applying it to barley seed in a slurry treater, add five-eighths pint of MEMA to 1 gallon of water (or 6¼ pints to 10 gallons of water) and apply 23 cubic centimeters per 10 pounds of seed. If it is to be applied in an oil-drum or barrel treater, mix 1⅜ gallons (or quarts) of MEMA with 8⅝ gallons (or quarts) of water (roughly 1 to 6) and apply 2 fluid ounces per bushel of seed.

Barley seed should be treated about a week before being sown. It should be stored in a well-ventilated place.

9. Merculine (10 percent of phenyl mercuric salicylate) is an emulsive oil solution of an organic mercury and mixes readily with water. It is applied to seed grain at the rate of one-half ounce per bushel, and may be diluted with 7 parts of water before application. Seed should be treated at least a week before sowing.

CAUTION

The liquid treatments Panogen, Setrete, MEMA, and Merculine are poisonous mercurial liquids and should be handled with care. They are colored red so that if splashed on the skin or clothing they are easily detected. Avoid skin contact with these chemicals—both concentrated and diluted—and wash at once with soap and water in case of accidental contact. If splashed in the eyes, flush with water for 15 minutes. Wear rubber gloves when treating seed, or when handling freshly treated seed. Treat seed in the open or in a well-ventilated room and away from feed and food. Do not use treated seed for food or feed, and do not store it near food or feed. All sacks of treated seed should be properly labeled.

CHART OF DISEASES, CAUSAL ORGANISMS, AND CONTROL MEASURES

Disease	Causal organism	Control measures
Covered smut	*Ustilago hordei*	Seed treatment, resistant varieties.
Nigra loose smut	*U. nigra*	Do.
Nuda loose smut	*U. nuda*	Resistant varieties, hot-water treatment.
Stem rust	*Puccinia graminis*	Resistant varieties, barberry eradication.
Leaf rust	*P. hordei*	Resistant varieties.
Powdery mildew	*Erysiphe graminis hordei.*	Do.
Scab or Fusarium blight.	*Gibberella* and *Fusarium* spp.	Seed treatment, cultural practices.
Stripe disease	*Helminthosporium gramineum.*	Resistant varieties, seed treatment.
Spot blotch	*H. sativum*	Resistant varieties, seed treatment, cultural practices, crop rotation.
Net blotch	*H. teres*	Seed treatment, crop rotation, resistant varieties.
Bacterial blight	*Xanthomonas translucens.*	Seed treatment, crop rotation.
Scald	*Rhynchosporium secalis.*	Resistant varieties, crop rotation, cultural practices.
Ergot	*Claviceps purpurea*	Crop rotation, clean seed, weed control.
Stripe mosaic	Virus	Resistant varieties, crop rotation.
Yellow dwarf	do	Aphid control, resistant varieties.
Root, foot, and crown rots.	*H. sativum* and species of Fusarium and other fungi.	Seed treatment, cultural practices, crop rotation.

U. S. GOVERNMENT PRINTING OFFICE: 1955

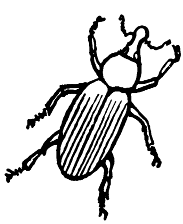
Clean Grain

Makes wholesome flour and cereal products

Cleanliness in grain begins on the farm

Insects, birds, and rats and other rodents that get into stored grain cause enormous losses. They waste the nation's food and eat away your profits. You can help cut these losses by making sure that all the grain you store and handle is clean.

Keep rats and mice out with better storage construction. Poison and trap rodents and clean up places where they may hide and live.



Keep insects out. Fumigate old stored grain. Before storing new grain, get rid of insects by cleaning the bins and areas surrounding them. Spray bins with insecticide.

Use screens to keep out birds and poultry. Use ½-inch mesh hardware cloth or similar material over all windows and other openings.

GRAIN IS FOOD • • • KEEP IT CLEAN